

migrates into the direction opposite to the osmotic phenomenon. The phenomenon is called "reverse osmosis", and, for example, for obtaining purified water from seawater by reverse osmotic method, it is necessary to apply to the seawater a pressure higher than the osmotic pressure of seawater.

(ii) Low-pressure reverse-osmosis (RO) membrane filtration

The RO membrane filtration has been used mainly in semiconductor manufacturing processes, for example, for production of the ultrapure water for cleaning used in the steps of production of silicon wafer and various printed circuit boards. After the ban on use of cleaning solutions of fluorinated hydrocarbons (Freons), which damages the ozone layer, ultrapure water produced by RO membrane filtration has been used gradually in a greater amount. The raw water is purified water, ion-exchange water, tap water, or the like, which has almost no osmotic pressure, and thus the RO membrane filtration can be performed at quite a low pressure.

However, in recent progress, the RO filtration technology is gradually penetrating into the market of seawater desalination, which relied so far only on distillation, and there is a need for high-pressure RO membrane filtration technology.

(iii) High-pressure RO membrane filtration

The osmotic pressure of seawater depends on the concentration of its salt, and seawater containing salt at a high concentration has a high osmotic pressure. The salt concentration of seawater in the seas surrounding Japan is about 3.5 (by weight) %, and those of the seawaters in the Mediterranean Sea or in the sea close to the Persian Gulf are said to be respectively 4.0 to 4.5 (by weight) %. The osmotic pressure of seawater at a salt concentration of 3.5% is about 25 kgf/cm² at 25°C. Normally, seawater containing salt at 3.5% is condensed first to seawater containing salt at around 6.0% (osmotic pressure: about 45 kg/cm²) by RO membrane filtration, and it is necessary to apply a pressure at about 60 to 65 kg/cm² to obtain purified water consistently and reliably from the seawater. A further higher pressure is desirable for improving productivity. Accordingly, the support for an RO membrane filter should have a property enduring such a pressure.

(2) Polyester fiber support resistant to high-pressure filtration

(i) Improvement in the dimensional stability of polyester fiber (meaning of specifying double refraction Δn)

Independent of whether a fiber is natural or synthetic, the microstructure of the fiber consists of crystalline and amorphous regions, and the ratio of the crystalline regions in the entire microstructure, or "crystallinity", is used as an indicator of the rigidity and stability of fiber. Commercially available drawn polyester staple fibers are normally controlled to a crystallinity of 30 to 40%, taking into consideration of the texture and the dye-affinity of the fibers. Deformation in the fiber or the nonwoven fabric produced therefrom occurs mainly in the amorphous regions, and the ratio of amorphous regions is desirably as small as possible to prevent the deformation.

It is important that the polyester fiber according to the present invention, which is drawn at a high stretching rate, have molecules highly oriented in the axial direction of the fiber. The degree of orientation is defined by double refraction Δn . Stretching/heat setting promotes crystallization of the fiber to a high degree. The heat setting usually give a fiber having a high crystallinity of 60% or more, improving the dimensional stability of the staple fiber and the webs thereof.

The fibers described in Goettmann seem to be common commercial fibers or fibers with a slightly lower than normal crystallinity (i.e. below 30% to 40%), as judged from the fibers exemplified. In column 4, lines 1-19 of Goettmann, disclosed are combinations of a 0.43-de polyester main fiber manufactured by Kuraray Co., Ltd. and a 1.0-de binder fiber (EP-101) manufactured by Kuraray, and a 2.0-de binder fiber manufactured by Kuraray and a 1.5-de main fiber manufactured by Hoechst Celanese.

The present inventors have used and know well about the EP043 polyester fiber manufactured by Kuraray. The fiber is a fiber having an extremely soft surface and a crystallinity of significantly lower than 30% that is produced in a stringent manufacturing process to make it thinner. Citation of such a fiber is evidence that technical concept of improving crystallinity is completely absent in Goettmann.

(ii) Control of micropore distribution of polyester fiber nonwoven fabric (meaning of specifying heat shrinkage stress at 200°C)

Filtration member supports should have through holes consisting of micropores in a suitable size. The micropores are preferably suitable in size and as many as possible in number. The distribution of the micropores is particularly preferably monodisperse, i.e., all micropores are the same in diameter, if possible.

If a support has just one excessively larger micropore, a pinhole may be formed in semipermeable membrane when a semipermeable membrane resin is applied on the support surface, and the resulting semipermeable membrane may possibly be broken by the high pressure applied during filtration.

When the pore size is too small, the semipermeable membrane resin may not be embedded in the pores because the resin solution does not penetrate into the support sufficiently, resulting in weaker adhesion and thus easier exfoliation of the membrane. Generally, the fibers are inevitably flattened during operation at high pressure for an extended period of time, and supports having micropores smaller in size often result in the failure of filtration because of collapse of the micropores. The phenomenon is more remarkable when a fiber having a lower crystallinity is used.

The most distinguishing feature of the present invention is that a method of forming a support having micropores with a uniform pore size distribution is developed successfully. Namely, the pore size is adjusted not by the conventional method of mixing higher-denier fibers, but by using the shrinking force of low denier fibers. The shrinking force is not endowed by a known highly crimped composite fiber, high-shrinkage fiber, or the like. Such fibers do not shrink when incorporated in webs such as nonwoven fabric, in which the fibers are restrained by external force, because of their low shrinking force. Desirable is not a fiber having a greater shrinkage percentage (%) but a fiber having a greater shrinkage stress (g/d).

The basic principle is as follows:

When a polyester fiber is drawn at a high draw rate, a greater stress is generated in the fiber. The stress is normally removed in the subsequent heat-setting step, giving a dimensionally

stable fiber. However, in the present application, a fiber having a residual strain is deliberately prepared by heat setting a polyester fiber at a temperature slightly lower than that for complete removal of the stress (resulting in that the polyester fibers used in the present invention has a heat shrinkage stress at 200°C of 0.10-0.60 g/d); and the fiber is cut into staple fibers having a particular length and sent to the subsequent sheeting step. When the web containing the fibers is processed in a heat-calendering step, the residual strain is relaxed completely by the heat applied thereto and the fibers shrink under the strong force, forming micropores in the web. The size of the micropores can be adjusted by controlling the fiber residual strain.

(3) Comparison of support member between the present invention and Goettmann

(I) Market of RO membrane filtration

Goettmann describes purification of saline water. Desirable loading reverse osmotic pressure varies according to the salt concentration, but Goettmann has no discussion on the pressure under which his support may operate nor on filtration of seawater. Water containing salt even at 1 ppm is also salt water, and it is not clear whether Goettmann is aimed only at low-pressure filtration or at both low- and high-pressure filtration.

(ii) Dimensional stability of support (meaning of mean value of breaking length at an elongation of 5%)

The breaking strength and the breaking elongation of a nonwoven fabric are often indicated as the properties of a support (nonwoven fabric) for RO filtration membrane. However, when exposed to a high-pressure filtration, for example, in seawater desalination, the semipermeable membrane is exfoliated from the support because of elongational deformation before the support is broken down. Thus, one of the requisites for the support for use in high-pressure filtration is dimensional stability (deformation resistance).

The breaking length at an elongation of 5% is adopted in the invention.

Heat-calender processing of the base web is particularly important in the present invention. In known prior arts including the cited reference, USP 5,851,355 (Goettmann), the main purpose of the heat-calender processing is described to be for connecting main fibers by fusing a binder fiber. However, in the heat-calender processing step of the present invention, in

addition to connection of the main fibers with the weldable binder fibers, the residual stress in the main fiber is also removed, allowing the fiber to shrink and the micropores to be formed in the nonwoven fabric by the shrinkage at the same time to provide the support with dimensional stability.

The properties of support member of Goettmann is summarized in the Table A below based on Table 1 of Goettmann.

Table A

	after calendared	JIS	present invention
basis weight (3000ft ²)	46.0	76.7 g/m ²	
thickness (mil)	4.0	0.102mm	
permeability (cfm) Frazier Air	5-10	2.5-5.1 cc/cm ² /sec	0.2-5.0 cc/cm ² /sec pore size $\leq 42 \mu\text{m}$
tensile (lb/in) MD CD	35.0 10.0	9.30kg/15mm 2.66kg/15mm	value of breaking length at an elongation of 5% mean value of (MD+CD) is 4.0km or more
elongation (%) MD CD	4.0 5.0	4.0 5.0	

The value of breaking length at an elongation of 5% in lengthwise direction (MD) of Goettmann is 0km (because elongation (breaking elongation) is 4%).

The value of breaking length at an elongation of 5% in crosswise direction (CD) of Goettmann is 2.3km.

Therefore, the mean value of breaking length at an elongation of 5% in lengthwise direction (MD) of Goettmann is 1.15 km ((MD+CD)/2=(0+2.3)/2).

The above described values of breaking length at an elongation of 5% are obtained as follows:

A value of breaking length at an elongation is based on JIS P8113 and obtained by the following formula:

Value of breaking length at an elongation (kg) = tensile strength (kgf)/(BxW)x1000

in which B represents width of specimen (mm), W means basis weight of specimen (g/m²).

Tensile [MD] of 35.0 (lb/in) = 15.75kg/25.4mm = 9.30kg/15mm,

Tensile [CD] of 10.0 (lb/in) = 4.5 kg/25.4mm = 2.66kg/15mm.

Therefore, the value of breaking length at an elongation of 5% in a lengthwise direction (MD) = $0/(15 \times 76.7) \times 1000 = 0\text{km}$ and the value of breaking length at an elongation of 5% in a crosswise direction (CD) = $2.66/(15 \times 76.7) \times 1000 = 2.3\text{km}$.

Thus, it is clear from Table 1 of Goettmann that the reference support member fails to possess the claimed mean value of breaking length at elongation of 5% of 4.0 km or more.

As described above, Goettmann is related to a staple fiber containing amorphous regions, that is extremely lower in crystallinity, i.e., easily deformed, and paid no attention to the dimensional stability of the web (nonwoven fabric) and suggests nothing informative about the method of improving dimensional stability to the present invention.

(iii) Micropore distribution

Goettmann discloses only the air permeability by Frazier method in Table 1 (Column 5, line 55)

The support member of the present invention is specified not only air permeability but also pore size (maximum pore diameter) of 42 μm. As described in the present specification, the maximum pore size of the nonwoven fabric is an index which indicates whether numbers of the fine pores are many or not when the air permeability is at the same time (line 23 to line 26 on page 31 of the present invention). In the case where the air permeability is same, if the maximum pore size is shown, uniform distribution of fine pores is predictable. Even when the air permeability is disclosed, the air permeability becomes the same as that of the present invention when only one big pore is formed. Important is the distribution of micropores. Even if the air

permeability is the same, it does not mean that the distribution of pores is uniform, and it does not disclose the preparation of the support member having a uniform distribution of pores.

The Frazier method, which is determined by using a terminal having a diameter about 7 cm (area: 38.5 cm²), is not effective in indicating the properties of the current support that demands uniform distribution of numerous micropores.

(4) With respect to elongation of Goettmann

The elongation of nonwoven fabric in Table 1 of Goettmann is 4.0% (MD) and 5.0% (CD). A semipermeable resin (for example, polysulfone) is casted and set on the nonwoven fabric support member to give a filter support member. In that process, it is not permitted that wrinkles, folds and irregularity of thickness appear based on tension irregularity. Practically, it is required that the nonwoven fabric support member has at least 15% of elongation because the support member cannot pass through the long and continuous casting/setting process. As mentioned above, the support member of Goettmann has just 1.15 km of mean value of breaking length at elongation of 5%, being completely inferior to the 4.0 km mean value of breaking elongation of 5% of support member of the present invention.

(5) Conclusion

As described above in detail, the object of the present invention is to attain "uniform micropore distribution" and provide the support with a "favorable dimensional stability even under high pressure" by controlling the microstructure of a polyester fiber for support in combination of fiber preparation and its processing method. Therefore, the present invention is completely different in both the technical concept and the substance from Goettmann.

Goettmann fails to suggest the claimed nowoven support member having a mean value of breaking length of 4.0 km. Goettmann fails to teach or suggest that the choice of polyester fibers according to the claimed invention, having a specified double refraction and heat shrinkage stress, are result effective variables.

In view of the foregoing, favorable reconsideration and allowance is respectfully solicited.

Respectfully submitted,

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August 16, 2005